4. PHYSICAL SETTING

This section provides an assessment of the physical setting of Ballona Wetlands. A summary of the biological resources is given in Section 5.

4.1 GEOLOGY

The alluvial sediments of Ballona Wetlands are underlain by the early Pleistocene age San Pedro Formation to a depth of 200 feet. Below depths of 200 feet lies a 5,800-feet sequence of Tertiary age sedimentary rocks which overlie metamorphic basement rocks of Mesozoic age Catalina Schist (Law/Crandall, Inc., 1991a, b). Portions of the area are underlain by oil deposits created by organic matter deposited long ago and subsequently covered by layers of rock and other sediments.

The bedrock beneath the coastal zone in the vicinity of Ballona Wetlands is characterized by faulting and tectonic activity. Although there are no faults known to pass directly below the project area, there are numerous fault systems in the vicinity including the Newport-Inglewood Fault, the Malibu Coast Fault, the Charnock Fault, the Overland Fault, the Santa Monica-Hollywood Fault, and the Palos Verdes Fault (Law/Crandall, Inc., 1991a, b). The Charnock Fault and the Overland Faults are the closest faults, located 1.3 miles northwest and 2.5 miles northeast of the wetlands, respectively. They extend in a northwesterly direction and act as a barrier to the flow of groundwater.

The original soils comprising Ballona Wetlands were derived from both fluvial and marine environments. A shift in relative dominance is visible in the sediment stratigraphy at around 50 feet depth, below which level, sediments are primarily alluvial, and above which sediments are mixed alluvial and estuarine. The alluvial sediments below 50 feet are primarily channel and floodplain sand and gravel and are referred to as the ‘Ballona Aquifer’ or ‘50-foot Aquifer’, whereas the mixed sediments above 50 feet consist of silt, clay and sand derived from the stream bed, floodplain, tidal flats and coastal dunes. Sand is more prevalent in the upper layers of soil profiles in locations close to the ocean due to the combined effects of littoral and wind transport and deposition.

The area was subsequently overlain by fill dredged during the construction of Marina Del Rey and excavated from the flood management projects of Ballona Creek. Fill materials are comprised of clay, silt, silty sand, and sand and range in depth from zero to 18 feet across Areas A and C (Law/Crandall, Inc., 1991a, b).

Liquefaction hazards have been investigated by the California Geological Survey (2001). In their evaluation report they noted high liquefaction susceptability for the beach, estuarine, and young alluvium deposits. These deposits account for most of the project area. Artificial fill in the Marina Del Rey area were considered too thin to affect the liquefaction hazard and no effort was made to determine their sub-surface characteristics (California Geological Survey, 2001).

4.2 CLIMATE

Southern California experiences a Mediterranean climate with moderate seasonal temperature fluctuation due to the marine influence. The Los Angeles Basin contains a number of microclimates affected by proximity of the ocean, prevailing wind direction and local topography. The Ballona Wetlands, located adjacent to the Santa Monica Bay, experience moderate temperatures and seasonal coastal fog caused by land-sea temperature differences during the summer.

The nearest long-term weather station is located at Los Angeles Airport. Daily (1944 - present) and monthly (1914 - present) records of temperature and precipitation can be found at the NOAA Western Regional Climate Center website (http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?calosa).

4.2.1 Temperature

Ballona Wetlands experience mild temperatures year round due to temperance by the adjacent ocean waters. The highest temperatures occur in June, July, and August. However, the temperature can fall in mid summer due to fog, making it warmest in late spring and early fall, with a mid-summer drop in temperature near the coast (Purer, 1942; Swift and Frantz, 1981). The average summer temperature for 1914 to the present was 68.9ºF and the average winter temperature was 57.1ºF.

4.2.2 Wind

Wind speed data is available for Los Angeles Airport. Average wind speed is 7.8 mph and the mean monthly wind speed varies between 6.5 mph in the winter (November) and nine mph in the spring (April).

4.2.3 Precipitation

The seasonal variation of high and low pressure systems determines the frequency and amount of rainfall. The Pacific Ocean provides a consistent source of moisture to the low pressure systems over the north Pacific. Saturated air masses reach the shore from areas to the west, resulting in precipitation.

The average annual precipitation at Los Angeles Airport is 13.5 inches for the period 1914 to the present. Average monthly precipitation for the same period is shown in Figure 4-1, describing high seasonal variation. Average winter (December, January, and February) precipitation was 8.26 inches while that of summer (June, July, and August) was 0.13 inches. The average seasonal distribution of the annual precipitation was:

Winter	61%
Spring	24%
Summer	1%
Fall	14%

Total annual precipitation has ranged from 4.4 to 30.5 inches per water year. The annual data at Los Angeles Airport (Figure 4-2) shows that most years are drier than the average annual of 13.5 inches while only a few are anomalously wet. Figure 4-2 therefore highlights the high interannual variability in precipitation. This variability is important because wet years typically drive many of the physical and biological dynamics of wetland systems (sedimentation events, low salinity events and plant recruitment, high stress years with little rainfall, etc.).

While there is not a consistent long-term trend in precipitation, there appears to be some cyclical component associated with the El Nino/Southern Oscillation phenomenon. El Nino events enhance precipitation and occur with varying intensity at a frequency of 7-12 years. Figure 4-2 shows increased precipitation in the late 1930's and early 1940's, early 1980's and mid-1990's, concurrent with strong El Nino events. Droughts of one to several years are common.

4.2.4 Evapotranspiration

Evaporation from the land surface and vegetation, and transpiration by plants is a significant element of hydrologic conditions at the project area. These processes, together called 'evapotranspiration', are affected by the length of solar exposure and temperature. They vary seasonally with changes in day length, temperature and solar intensity. During winter months when precipitation is greatest, evapotranspiration rates are low, while during the summer months evapotranspiration rates are highest.

The estimated annual evaporation rate for coastal Southern California is about 26 inches of water per year. Average annual precipitation is 13.5 inches, indicating a general moisture discrepancy. The excess of evaporation over precipitation results in the loss of large amounts of water to the atmosphere following rainfall events. Standing water accumulations within small depressions are ephemeral and soils remain dry most of the time. During wet years, precipitation may exceed evaporation during the winter months, resulting in the wetting of the soils. However, on average, precipitation rates during the winter do not exceed winter evaporation rates and soils do not experience extensive long-term wetting (Straw, 1987).

4.3 TIDES

Santa Monica Bay experiences mixed semidiurnal tides, with two high and two low tides of unequal heights each day (Figure 4-3). In addition, the tides exhibit strong spring-neap tide variability; spring tides exhibit the greatest difference between high and low tides while neap tides show a smaller than average range (Figure 4-4). The spring-neap tides also vary on an annual cycle, with the highest spring tides occurring in June-July and December-January and the weakest neap tides occurring in March-April and September-October.

The National Oceanic and Atmospheric Administration (NOAA) tidal datums for the 1983-2001 epoch for Los Angeles tide gauge are summarized in Table 4-1 and Figure 4-5. This table also illustrates the differences of the 1983-2001 datums with those from the previous epoch. The mean tidal range, defined as mean high water (MHW) minus mean low water (MLW) is 3.81 ft, and the diurnal tidal range defined as mean higher high water (MHHW) minus mean lower low water (MLLW) is 5.49 feet.

Table 4-1. NOAA Tidal Datum for the 1983-2001 Epoch for Los Angeles Tide Gauge

	MLLW (ft)	MSL (ft)	NGVD 29 (ft)	NAVD 88 (ft)
MLLW	0.0	-2.82	-2.63	-0.21
MLW	0.94	-1.88	-1.69	0.74
MTL	2.84	0.02	0.21	2.64
MHW	4.75	1.93	2.12	4.55
MHHW	5.49	2.67	2.86	5.29

Tides propagate through the mouth of Ballona Creek and influence surface water elevations upstream to the Centinela Bridge (USACE, 2000). Tidal flow is restricted primarily to Ballona Creek. In Area A, tidal flow enters Marina Ditch through a culvert connecting it to Marina Del Rey. In Area B, a series of flap-gates, and more recently self-regulating tide-gates, have allowed muted tidal flows to enter the wetlands.

4.3.1 Sea-Level Rise

Historical trends in relative sea level are measured at tide gauges which capture relative vertical movements of the land as well as changes in the global or eustatic sea level. These records measure the local rates of sea-level rise relative to the coast. NOAA (http://co-ops.nos.noaa.gov/sltrends/sltrends) estimates that relative sea levels have been rising at a rate of 0.84 $mmyr^{-1}$ (0.28 ft/century) at the Los Angeles tide gauge (1924–1999) and 1.59 $mmyr^{-1}$ (0.52 ft/century) at the Santa Monica tide gauge (1933–1999) (Figure 4-6). The historical relative sea-level rise at Ballona Wetlands is likely to be between these two estimates because the Los Angeles tide gauge is subject to the impacts of uplift (along the Newport-Inglewood fault) and the Santa Monica tide gauge may exhibit some subsidence.

The Intergovernmental Panel on Climate Change (IPCC) estimated that the future rate of sea-level rise will likely accelerate. IPCC (2001) predicted that global sea level will likely rise by between 0.08 m (0.25 ft) and 0.8 m (2.6 ft) by the year 2100. Cayan et al. (2006) indicated a global sea level rise of between 15 and 17 cm (0.49 and 0.56 ft) by 2050 and between 26 and 39 cm (0.85 and 1.28 ft) by 2100 based on the median values for a range of greenhouse gas emission scenarios. Extreme high water levels may change more than mean sea level due to alterations in the occurrence of strong winds and low pressures. However, this has not been extensively studied for the project area (IPCC, 2001).

4.4 SOURCES OF INFLOWS

Inflows to the wetlands, combined with their morphology, create the hydrologic regime of the project area. This has a major influence on the type of vegetation present and helps establish the internal channel network. The potential amount of water contributed, frequency of contribution, type of water contributed (saline, fresh, polluted) and flows into the wetland system are important in the consideration of the hydrologic functions of the wetland.

The potential inflows to Areas A, B and C are shown on Figure 4-7. These inflows include:

- Ballona Creek
- Marina Del Rey
- Urban Runoff and Stormwater
- Groundwater

4.4.1 Ballona Creek

Ballona Creek drains an area of approximately 130 square miles, 80% of which is urbanized while the remaining 20% is composed of partially developed foothills and mountains. While some of the headwaters remain in their natural form, the majority of the Ballona Creek drainage network has been modified into storm drains, underground culverts and open concrete channels. Ballona Creek, in the vicinity of the project area, has an earth invert with quarry stone backfill and grouted stone side slopes. All of its tributaries flow in either concrete channels or culverts. Table 4-2 summarizes the runoff flow conditions of Ballona Creek at Sawtelle Boulevard for return periods ranging from one to 500 years. The channel is designed to discharge a 500-year storm at capacity.

Streamflow data from the period of record between 1935 and 2005 reflect mean daily winter/spring flows of 82.1 cubic feet per second (cfs) and mean daily summer/fall flows of 19.8 cfs. The range of the seasonal mean daily flows is evidence of the seasonality of precipitation and the relative insignificance of snowmelt during the dry season. The difference between the maximum flow and the mean daily flow for winter (the wet season) is indicative of the episodic nature of large rainfall events.

Table 4-2. Ballona Creek Extreme Runoff Flow Conditions at Sawtelle Boulevard

Return period (year)	Discharge (cfs)
1	7769
5	17657
10	22000
50	32135
100	36020
200	38103
500	44283

Source: USACE, Marina Del Rey and Ballona Creek Feasibility Study (2003).

The movement of sediment within Ballona Creek has been greatly altered from natural conditions over the 20th century. Development of the Ballona Creek watershed and channel straightening has modified both the sediment supply and the ability of flows to transport sediments. Additionally, channelization of the creek has cut off the banks and floodplains of the natural river. Sediments carried in flows are not stored within the banks but are rather transported to the outlet of Ballona Creek where they are deposited. The USACE periodically dredges the mouth of Ballona Creek and Marina Del Rey to prevent sediment build-up.

The Los Angeles County Department of Public Works (LADPW) monitors suspended sediment concentrations (SSC) within Ballona Creek at a stream gauge near Sawtelle Boulevard during wet events and dry periods in accordance with their NPDES permit requirements. Their monitoring results show a wide range of suspended sediment concentrations that are largely dependent upon antecedent dry period as well as streamflow.

Suspended sediment concentrations are greatest during storm flows that follow long periods of dry weather. As shown in Figure 4-8, the greatest SSC of a cluster of events occurring around the same time, consistently appear to be in the first event. Additionally, dry weather SSCs tend to be much less than those during storm events. Dry weather SSC between 1998 and 2004 range from five to 84 mgl^{-1} while wet weather SSC range between 26 and 908 mgl^{-1}.

It is estimated that approximately 60,000 yd^3 of sediment moves through the system on an annual basis, of which about 90% (54,000 yd^3) is sand and 10% (6,000 yd^3) is silt (USACE, 2003). An adequate supply of fine-grained sediment is important to tidal wetlands, firstly to allow them to attain equilibrium with respect to tide elevations, and secondly to maintain that equilibrium with rising sea levels.

4.4.2 Marina Del Rey

Marina Del Rey harbor opens to the Pacific Ocean in Santa Monica Bay. As shown on Figure 1-1, the mouth of Ballona Creek to Santa Monica Bay is shared with the entrance channel to Marina Del Rey and separated by a jetty. The entrance channel is split into two channels located adjacent to the north and south sides of a detached breakwater, referred to as the North and South Entrance channels. Marina Del Rey is located in unincorporated County of Los Angeles, surrounded by the city of Los Angeles and Culver City. The Marina was developed in the late 1950’s and early 1960’s on parts of the former Ballona Wetlands, the jetties were completed in 1959 and the breakwater was added in 1965. The current area of the Marina Del Rey watershed is approximately 2.9 square miles and drains a highly urbanized area with land use that includes residential, commercial and industrial. The Marina is the largest artificial small-craft harbor in the U.S. and accommodates more than 5,000 privately owned pleasure craft.

Periodic maintenance dredging of the North and South Entrance channels, the Main Entrance channel and the mouth of Ballona Creek is undertaken to maintain navigable depths (Figure 4-9). Marina Del Rey has a significant build-up of sediments that affects the safety of navigation. Routine maintenance dredging has been hindered by the lack of suitable disposal sites for the contaminated dredged material. Marina Del Rey is directly connected to Areas A and C through a culvert under Fiji Way that connects to Marina Ditch (Figure 1-1).

4.4.3 Urban Runoff and Stormwater

Inflows from urban runoff and storm drains are important sources of freshwater for Area B and the Freshwater Marsh, in particular. These inflows are described for each individual area in the following sections. No sediment concentration data related to bluff erosion, freshwater urban runoff and stormwater has been identified.

4.4.4 Groundwater

Historically, Ballona Wetlands received water from artesian upwellings (Hendrickson, 1991a).At the turn of the 20th century, the water table in the project area was about 10 feet MSL and those areas of the wetland with an elevation below 10 feet received water from this source. Therefore, artesian water may well have played a significant role in the development of the wetland.

Straw (1987) described the groundwater distribution in Areas A, B and C. Although the historic level of groundwater was high, today it is much lower. Groundwater is present in the surficial materials forming an unconfined water table aquifer under Area B. The water table ranges in elevation from 1.0 feet MSL to -2.0 feet MSL. Recharge to the water table aquifer is by infiltration through the soil column following rainfall events and during inundation of the soil by surface water. The level fluctuates seasonally between wet and dry years and also reflects longer-term cycles in precipitation.

Straw (1987) also described a confined aquifer with artesian pressure under Area B. The groundwater is strongly controlled by the adjacent uplands, which act as recharge areas for the confined aquifers, and by Ballona Creek and the coast which are discharge areas. The water table, therefore, slopes from the Del Rey Bluffs towards Ballona Creek. The inflow of groundwater into Area B is indicated by the reduced occurrence of salt water and the presence of willows (generally salt water intolerant) along the base of the bluff slope.

No major part of Areas A and C receive standing water from groundwater discharge, with the possible exception of seepage into Marina Ditch. There are observations of ‘shallow’ groundwater or ‘perched’ water tables that appear to be occurring in Area A (at least in wet years).

4.5 AREA A

4.5.1 Topography

Area A includes 139 acres and is bounded by Marina Del Rey channel on the west, Ballona Creek on the south, Fiji Way to the north and Lincoln Boulevard to the east. Figure 4-10 is an oblique aerial photograph of Area A from 2000 and Figure 4-11 shows its topography. The entire marsh surface is buried under fill material, which occurred during several periods of filling in the 20th century. Present surface elevations appear similar to those immediately after the discharge of fill material, with only slight modification by surface runoff and shallow subsidence as the fill dried and consolidated. In general, the perimeter of Area A is slightly higher, and slopes down to a central shallow depression.

Fill was placed in the southeast corner at the beginning of the 20th century for the construction of the Pacific Electric Railroad levee, which can also be traced through Areas B and C. In the 1920's platforms were constructed in the southwest corner of Area A by placing fill on the marsh surface so that oil production facilities could be placed above extreme high tide levels. Surface elevations of up to 18 feet MSL occur in this area. During the channelization of Ballona Creek, dredged material from the channel was sidecast to construct the levee and this forms the southern boundary of the area. The eastern portion of the area was filled in the early 1960's with the hydraulic disposal of dredged material from the excavation of Marina Del Rey boat basin and channel. This was placed on the remaining marsh to the east of the oil platforms, raising land elevations to about 15 feet MSL.

The topography and distribution of sediments suggests that the Marina Del Rey fill occurred as follows (based on Straw, 1987). The western margin was produced by pumping material from the Marina Del Rey channel through outlets positioned along the channel. These formed high areas close to the channel, such as between the oil platforms and the northern margin of the area. The discharge of dredged material was then directed from the margins towards the interior of Area A. The competence and capacity of the flows decreased with distance from the outlets positioned along the channel. As a result, coarser sand was deposited close to the margins of the site and fine sand and coarse silt formed the slopes extending between the margin and the stilling basin depression. The silt and clay, which would have been held in suspension, settled out in the stilling basin formed by the north-south ridges, the Ballona Creek levee and Marina Ditch.

Excess water from the stilling basin was decanted through the northern dike through a corrugated metal pipe, acting as an overflow weir, and into Marina Ditch. This water would have had relatively low sediment concentrations.

As a result of this process of filling, the topography of Area A is characterized by three sub-divisions that run north-south, almost perpendicular to Ballona Creek. The western third of the area contains a series of ridges and platforms that separate a number of isolated depressions. This portion is separated from the eastern two thirds of the area by a low, wide, ridge running north-south from the oil and gas facilities to Marina Boulevard. The eastern third of the area is about 600 feet wide, bounded by Lincoln Boulevard and a narrow sharp ridge that runs north-south to Marina Ditch. Within this area the surface slopes westward. The central third is a broad, shallow depression bounded by the two ridges. This is the remnant of the 'stilling basin' used during the filling process.

4.5.2 Sediments

Converse Consultants (1981) conducted a geotechnical investigation of Area A, taking 28 borings, which varied in depth from 20 to 100 feet. The boring results showed that while the thickness of sediment layers varied a little, in general, sediment stratigraphy for Area A is spatially consistent.

Area A is covered by an extensive layer of fill that ranges in thickness from nine to 18 feet in the western portions to zero feet in the eastern portions. The fill material is comprised of loose to medium dense sand, silty sand, silty clay, clay, clayey silt, sandy silt and silt which becomes wet at depths of 0.3 to five feet. The fill material is underlain by a layer of soft to firm silty clay and clay with intervals of silt and sand ranging in thickness from 15 to 30 feet. This, in turn, is underlain by firm to stiff silty clay and clay with interlayers of silt and sand which are zero to 25 feet thick. Underlying the alluvium, at approximately 90 feet depth, is dense sand with gravel. The compressibility of the sediments decreases with depth while shear strength increases with depth. The top two layers appear to correspond to the fill layer and buried marsh deposits.

The oil platforms appear to have been constructed with poorly sorted coarse fill. Fill in the center is a mixture of dredged fill deposits from Marina Del Rey and dredging dumped from Ballona Creek – these tend to be relatively fine sediments. In the southeast corner, along the railroad levee, the fill tends to be sandier. This may reflect the dredging of deltaic deposits of Ballona Creek prior to channelization.

Borehole data from Converse Consultants (1981) and Law/Crandall, Inc. (1991a) show a general relationship between fill thickness and the elevation of the surface of the underlying marsh deposits. The original marsh surface can be as low as two feet below MSL beneath a fill thickness of 17 feet rising to four fet above MSL for fill thicknesses less than two feet. This indicates a potential subsidence of the original marsh surface of up to six feet depending on the thickness of the fill overburden.

4.5.3 Hydrology

Marina Ditch, which runs along the northern boundary of Area A, is connected to Basin H in Marina Del Rey via culverts under Fiji Way. In Area A this straight, unlined, trapezoidal channel appears to have been cut to allow dewatering of dredged fill from Marina Del Rey. The ditch channel continues into Area C where it appears to follow an old creek alignment. It drains stormwater from approximately 163 acres of existing development north of Area C, drains major parts of Areas A and C and accepts occasional overflows from Alla Road and Lincoln Boulevard North Storm Drain. The portion of Marina Ditch in Area A is tidal.

Surface drainage follows three main pathways as shown in Figure 4-11 (Straw, 1987).

1. A number of small areas drain to closed depressions. These are found to the north of the oil platforms and in the former stilling basin. These areas are isolated from Marina Ditch.
2. A narrow margin drains from around the northern perimeter directly into Marina Ditch.
3. Most of the area drains to the site of the former ‘stilling basin’. The stilling basin overflows and conveys water to Marina Ditch. In the winter and spring of 2005 ‘springs’ were day-lighting and flowing from the former stilling basin into Marina Ditch.

The hydrology of the area is strongly influenced by the permeability of the fill layers and therefore the manner by which the fill was placed. Infiltration rates in the southwest corner of the area are high due to the coarseness of the fill around the oil and gas facilities. Along the northern margin, adjacent to the Marina Del

Rey dredge pump outlet, the soils are also permeable. The area has relatively steep slopes, so that surface water infiltrates or flows downslope. Water collects in the low depressions north of the oil and gas facilities and in the stilling basin where the surficial and underlying materials are fine-grained and relatively impermeable. The amount of water that can accumulate in the depressions is a function of:

- Rainfall – frequency, intensity, duration;
- Depth of depression;
- Permeability of underlying soils; and
- Evapotranspiration rate.

Standing water in Area A can only persist in depressions of low permeability i.e. where fine silt and clay has been deposited and which lie below the elevation of the flow path to the Marina storm drain. These depressions would only tend to fill in winter when precipitation is high and evapotranspiration rates are low. A detailed description of depressions which retain water is provided by Straw (2000) and further mapping of ponding in the area was conducted by Hodder (J. Hodder, personal communication). These depressions have hydrologic functions that affect the distribution of vegetation and wetlands characteristics.

4.6 AREA B

4.6.1 Topography

Area B covers 338 acres, bounded on the north by Ballona Creek, on the south by the Del Rey Bluffs, and lies between Lincoln Boulevard and Playa Del Rey (Figure 4-12 and Figure 4-13). The hypsometry (the distribution of land area at different elevations) of Area B is depicted in Figure 4-14. This area was not filled as extensively as Areas A and C and the topography reflects natural marsh features as well as more recent grading associated with the construction of oil platforms and access roads.

Area B is bisected by roads that significantly affect its hydrology. In previous studies, Area B has been sub-divided into four smaller areas that conform more closely to the hydrology. These are:

- North Wetland: the area north of Culver Boulevard, west of the Gas Company road, south of Ballona Creek and east of Playa Del Rey;
- South Wetland: located north of the Del Rey Bluffs, west of the Gas Company road, south of Culver Boulevard and east of Playa Del Rey;
- East Wetland: located north of the Del Rey Bluffs, west of the Freshwater Marsh, south of Jefferson Boulevard and east of the Gas Company road. This area includes the alluvial fan at Hastings Canyon, and the lower portions of the Del Rey Bluffs;
- Northeast Wetland: located north of Jefferson Boulevard, south of Ballona Creek and east of the Gas Company road.

The lowest points of the North Wetland are located near Centinela Ditch and Jefferson Drain. The land surface adjacent to these ditches is low (from zero to +2 feet MSL) and reflects the old marsh surface. At the western and southwestern margins of the wetland, the area is bounded by dunes. To the east, the land rises to just over seven feet MSL. Bisecting the North Wetland is the berm of the abandoned Pacific Electric railroad which runs parallel to Culver Boulevard along most of the eastern and southeastern margins of the wetland. In the middle of the North Wetland, fill was placed to create elevated oil well platforms and connecting service roads, although the intervening surface appears to be the original marsh surface. Along the northern boundary with Ballona Creek, dredged material from the construction of the channel was deposited inside the levee on the marsh surface.

The South Wetland is relatively flat with surface elevations ranging from 2.0 to 2.8 feet MSL. Construction of pipelines and other oil and gas facilities in addition to the side-casting of material from ditches, elevated parts of the South Wetland to up to 3.0 feet MSL. The Gas Company facility is constructed at the base of the Del Rey Bluffs. North of the facility, alluvial sediments and eroded material from the bluffs have extended into the southern portion of the wetland. Centinela Ditch crosses the South Wetland, passes through the Gas Company facility and flows in a westerly direction under Culver Boulevard. Previously the flow from Jefferson Drain was conveyed in a ditch that extended in a southwesterly direction to a point just north of Centinela Ditch. The Jefferson Drain is now routed through the Freshwater Marsh before discharging to Ballona Creek.

The East Wetland can be divided into an eastern and western section separated by an alluvial fan that extends from the now-filled Hastings Canyon northwards into the wetland. To the east, the ground slopes gently from Jefferson Boulevard south toward Centinela Ditch. The surface elevation ranges between four feet MSL in the north down to three feet MSL in the south. This land was used for agriculture (lima beans and barley) from the 1930’s to 1985 (Sanders, 2000) and evidence of tilling is visible. To the west of the fan, the land surface slopes from the northeast to the southwest with a broad shallow depression just east of the Gas Company road. A low swale is evident which appears to follow the former course of Centinela Ditch. Near the abandoned outlet to the Jefferson Drain, mounds of material excavated during its construction have been deposited. The southern margin of the East Wetland is a low area between Del Rey Bluffs and Centinela Ditch.

The Northeast Wetland is enclosed by the Ballona Creek levee and by fill from the construction of Lincoln, Culver and Jefferson Boulevards. The gently undulating surface lies between 3.0 and 7.5 feet MSL. The lowest area is to the south of Culver Boulevard and elevations increase westward.

4.6.2 Sediments

The sedimentary characteristics of Area B are discussed in a geotechnical report by Crandall and Associates (1987). They recovered 18 borings which spanned Area B diagonally from the northeast to southwest. They found that sediments in the upper 50 feet were fine-grained while those below 50 feet were composed of nearly uniform sand and gravel. The western portion of Area B, which is closest to the ocean, are rich in sand; the deeper sediments are predominantly sand while the shallow sediments are a mix of silt and sand. In contrast, the eastern portion of Area B is rich in clay and silt. The upper layers of sediment contain abundant clay and virtually no sand. There was very little organic sediment found in any of the borings.

4.6.3 Hydrology

The sources of water to Area B include direct precipitation, tidal flow through gates along the Ballona Creek levee, and runoff from the Del Rey bluffs and the commercial district of Playa del Rey. Freshwater input to Centinela Ditch and Jefferson Drain was rerouted into Freshwater Marsh following its construction. Freshwater seepage is also suspected to be an important influence along the base of the bluffs.

4.6.3.1 Tidal Connection

The construction of Ballona Creek levees in 1932 isolated the existing Ballona Wetlands from the regular tidal influence of Santa Monica Bay. Until 2003, two sets of flap-gated culverts were located within the south levee of Ballona Creek. Their failure to close completely allowed some tidal exchange with the wetlands due to the ocean wave surge in the channel that would open and close the gates by changing water pressure as the wave passed. Psomas (1998) monitored the flap-gates and found that flood tides flowed through the tide-gates at an average flow rate of eight cfs and a maximum flow rate of 12 cfs. At a maximum, 11 acre-feet of salt water was exchanged, which flooded three acres of tidal channels. However, it was found that during spring tides, higher water levels were sometimes achieved within the wetlands than in Ballona Creek. At the same time, freshwater runoff from Centinela Ditch would also pond within the wetlands.

The east channel (of the North Wetland) flap-gates were replaced with self-regulating tide-gates (SRTs) (Table 4-3 and Figure 4-15) installed as part of the USACE 1135 project, allowing control over the tidal inundation and existing habitat functions. The replacement of the flap-gates with the SRTs allows controlled tidal exchange and increased marsh salinity. The frequency of inundation has increased as the tidal inundation occurs daily to a fixed elevation. The SRTs allow for flood tide flows to fill the wetland to 3.6 feet MLLW (0.78 feet MSL) (this elevation may be increased to about +4.0 feet MLLW or 1.18feet MSL).

The west channel of the North Wetland is connected to Ballona Creek by a 36-inch corrugated metal pipe (CMP) (invert of -3.72 feet MSL) with a flap-gate on the creek side (Table 4-3 and Figure 4-15). The culvert with flap-gate on the west channel prevents tidal flows from entering the wetlands while allowing the drainage of flood waters.

4.6.3.2 Channels and Flow Structures

Internal circulation of inflows occurs via the channel networks which are connected by culverts (Table 4-3 and Figure 4-15) under Culver Boulevard and the Gas Company road. In the past there were significant freshwater flows along Centinela Ditch and the Jefferson Drain.

In the North Wetland, the west channel is approximately 12 to 15 feet wide while the east channel varies in width from six to 15 feet near Culver Boulevard, to 45 feet at the Ballona Creek culverts. Each channel is about 1.5 to four feet deep. The improved tidal connection with Ballona Creek through the SRT has increased the tidal prism of the North Wetland and evidence of this can be seen in the localized erosion of the east channel along its banks. This represents the natural enlargement of the channel in response to greater tidal prism. Under average high tide conditions with the old flap-gates (and probably similar with the SRT), salt water flows eastward from the North Wetland under Culver Boulevard into the South Wetland. Occasionally, tidal flows can reach under the Gas Company road into the East Wetland.

Within the North Wetland, between the sand dune complex and the oil well platforms, the water table is within one foot of the land surface and the soils are saturated for extended periods during most years (Straw, 1987). Areas along the margins of the channels south of the abandoned Pacific Electric Railway show similar hydraulic conditions. East of the oil well platforms, a low enclosed area also has saturated soils for extended periods due to precipitation.

The east and west channels of the North Wetland are connected to the South Wetland via two 24-inch, one 18-inch, and one 42-inch reinforced concrete pipes (RCPs) under Culver Boulevard (Table 4-3 and Figure 4-15). Within the South Wetland, flows are confined to Centinela Ditch and the Jefferson Drain, both of which are approximately 27 feet wide and 0.3 to 0.6 feet deep.

The South Wetland is connected to the East Wetland via two 42-inch and one 60-inch corrugated metal pipes under the Gas Company road. The area to the west of the Hastings Canyon alluvial fan contains a low swale and a closed depression adjacent to the Gas Company road. This was created by the construction of the Gas Company road which blocked flows down the natural slope causing this area to pond. The Centinela Ditch was partially blocked in the early 1990’s by the expansion of the alluvial fan. Complete blockage occurred in the winter of 1997/1998, redirecting water from the ditch to flow through breaches in the Centinela Ditch berm northward into the eastern portion of the East Wetland (formerly an agricultural field). The water flowed northwest into the ditch extending westward to the Jefferson Drain. The alluvial fan is now a relict feature following the filling of Hastings Canyon.

Table 4-3. Details of Primary Flow Control Structures in Area B

Structure ID	Label	X	Y	Description
1	2 x 3.5 feet CMP	367119.76	3759298	Between South and East Wetland (Gas Co. Access Rd)
2	1 x 5 feet CMP	367089.96	3759338	Between South and East Wetland (Gas Co. Access Rd)
3	1 x 1.5 feet RCP	367036.99	3759444	Between South and East Wetland (Gas Co. Access Rd)
4	1 x 3.5 feet RCP	366717.65	3759125	Between South and North Wetland (Culver Boulevard)
5	2 x 2 feet RCP	366635.31	3758996	Between South and North Wetland (Culver Boulevard)
6	1 x 3 feet CMP flapgate	366017.72	3759145	Between N. Wetland (west channel) & Ballona Creek
7	3 x 5 feet CMP w/ SRT	366161.83	3759246	Between N. Wetland (east channel) & Ballona Creek
8	Tidegate(open usually)	365806.24	3759022	Del Rey Lagoon to Marina Del Rey
9	Tidegate(open during day)	365600.38	3759372	Ballona Lagoon to Marina Del Rey
10	1 x 10 feet culvert	366895.44	3760430	Marina Del Rey to Fiji Ditch
11	1 weir	367350.21	3760639	Lincoln and Fiji Way
12	2 x 1.5 feet culverts	368063.25	3759580	Lincoln and Freshwater Marsh
13	1 flapgate	367275.35	3759978	Ballona Creek to Freshwater Marsh
14	1 tidegate	365759.84	3761503	Oxford Basin
15	5 culverts	364704.41	3760951	Washington Street.

CMP = Corrugated Metal Pipe; RCP = Reinforced Concrete Pipe; SRT = Self-Regulating Tidegate

4.6.3.3 Stormwater or Runoff

The primary source of freshwater into Area B occurs via storm drains. Prior to the construction of the Freshwater Marsh, runoff entered the East Wetland from the Lincoln Boulevard and Jefferson Boulevard Drains, Centinela Ditch and the Del Rey Bluffs. At that time, the tributary area draining directly into the East Wetland was approximately 1,177 acres including 367 acres to the Jefferson Drain, 85 acres to the Lincoln Drain and 560 acres to Centinela Ditch. The Freshwater Marsh was designed to receive stormwater runoff from the Lincoln and Jefferson Boulevard Drain, the central storm drain and the eastern portion of the Del Rey Bluffs for discharge into Ballona Creek. Only major storm flows are allowed to overflow into Area B, though at present the adjustable weirs at the outlet have retained these flows in the Freshwater Marsh. Therefore, the freshwater discharge to Area B has diminished considerably.

Runoff into the South Wetland is from the Del Rey Bluffs in the vicinity of Falmouth Avenue and from the Gas Company facilities at the toe of the bluffs. Falmouth Avenue drains most of the Del Rey Bluffs to the west. Parts of the wetlands fill with standing water when Centinela Ditch floods but these drain relatively rapidly as the land slopes towards the channels. The South Wetland also receives flows from the East Wetland, and urban runoff from Culver Boulevard near Nicholson Street.

The majority of inflows to the North Wetland are surface runoff from within the area and stormwater flows from the South Wetland. The only direct inflow into the North Wetland is from the Pershing Drive Drain which occasionally overflows. Urban runoff from the commercial district of Playa del Rey also enters the tidal slough system from both sides of Culver Boulevard.

Along the southern boundary of the South and East Wetlands, water seepage from the Del Rey Bluffs is significant, particularly for the area between the West Bluffs and the Centinela Ditch. Rainwater ponds in this low-lying area as the low mound that runs along the channel prevents water from draining back to the ditch.

4.6.4 Freshwater Marsh

The Freshwater Marsh (26 acres) is located in the eastern portion of Area B (Figure 4-16). It receives stormwater runoff flows from the central inlet that drains the Playa Vista development and the Jefferson Boulevard drain. It is designed to accommodate runoff generated by a 1-year frequency storm event and smaller. Water flows into the marsh year-round from the storm drains and an adjustable outlet weir allows for water level control. The marsh will also receive water from the riparian corridor restoration project that will run between Loyola Marymount University and the Playa Vista development.

Stormwater runoff that discharges into this marsh flows southwest to an outlet weir (Figure 4-15 and Figure 4-16) that maintains water elevations in the marsh. The invert elevation of the structure is –2.8 feet MSL, with the top of the weir at 4.0 feet MSL. The Freshwater Marsh outlet flows into an underground culvert that flows northwards under Jefferson and Culver Boulevards and discharges into Ballona Creek. Flap-gates prevent the flow of tidal water in Ballona Creek back into the Freshwater Marsh.

The marsh also includes a spillway that is designed to allow overflow into a siltation pond and then into the East Wetland of Area B. If overflow did occur, the siltation pond would act as a sediment trap to reduce sediment entering the East Wetland during storm events. Flashboard weirs have been constructed which could be removed to allow the Freshwater Marsh to be hydrologically connected to Area B. In addition, a sluice gate is located at the southern end of the marsh that could be used to manage the periodic release of freshwater into the East Wetland.

4.7 AREA C

4.7.1 Topography

Area C covers an area of 66 acres and is located south of Marina Village, north of Ballona Creek, and extends eastwards from Lincoln Boulevard to the Marina Freeway (Figure 4-17 and Figure 4-18). Area C was filled in the early 1960's with material dredged from the Marina Del Rey boat basin. The fill covered the existing marsh and significantly raised the land surface elevation. The area is divided by Culver Boulevard.

Some fill was placed during the construction of the Pacific Electric Railroad levee in the southwest corner of Area C. More recently fill has also been associated with highway construction. However, the largest impact on the area was the hydraulically placed fill from Marina Del Rey. Slurry was pumped onto Area C, with the excess water returning to the boat basin through Marina Ditch. When the fill had been completed the channel was left in place as an extension of the drain. This left Area C with a high central area, sloping down to the perimeter. The resultant sloping topography does not retain water for extended periods of time (Straw, 2000).

The southern section of Area C, south of Culver Boulevard, is filled very high. Baseball diamonds and a parking area are located in this area.

4.7.2 Sediments

Law/Crandall, Inc. (1991a, b) conducted a geotechnical investigation of Area C for the Playa Vista development. The boring results indicated that the plot is covered by 3.5 to 15 feet of fill consisting of sand, silt, and clay with variable amounts of debris. Like Areas A and B, the fill is underlain by Holocene alluvium consisting of silt, clay, elastic silt and layers of sand and silty sand. The clay in the borings was expansive, and ranged from medium stiff to stiff. The silt was medium stiff to stiff while the elastic silt was soft. The interbedded layers of sand and silty sand are medium dense to dense. At depths of 41 to 57 ft, the sediments transition into dense to very dense sand and gravel, as occurs in Areas A and B. Holocene alluvium is estimated to extend down to depths of 100 ft, under which lies the early Pleistocene age San Pedro Foundation to about 200 feet.

Sandy sediments are found along the line of the Pacific Electric Railroad levee, which was constructed from dredging of Ballona Creek.

4.7.3 Hydrology

The hydrology of Area C results from a combination of direct precipitation, runoff from Area C, flow in Marina Ditch and water backed up behind flap-gates (Straw, 2000).

Marina Ditch is an open channel that runs along the western third of the northern margin of Area C and then extends diagonally to the southeast across the northern half of Area C (this last section appears to follow the line of an old marsh creek). This channel connects to Area B under Lincoln Boulevard.

Straw (2000) identified direct precipitation and overflows from storm drains as the main inflows to Area C. The Alla Road Storm Drain collects water from approximately 246 acres off-site and from smaller storm drains north of Area C, and discharges into Ballona Creek. The drain has no input from Area C. The Lincoln Boulevard North Storm Drain takes runoff from a portion of Lincoln Boulevard north of Ballona Creek.

During flood events on Ballona Creek, the flap-gates on the storm drain close and back-up may cause overflows to occur. These overflows are conveyed to the open channel in Area C to Marina Ditch. Marina Ditch passes through a culvert under Lincoln Boulevard. The hydraulic connection allows only minimal tidal exchange. Rainstorms which are of sufficient intensity to close the Alla Road Storm Drain flap-gates are infrequent and brief and likely to generate runoff from the surface of Area C into the open channel (Straw, 2000).